INTERACTION AND REMOTE SENSING OF SURFACE WAVES AND TURBULENCE

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LONG-TERM GOAL

The long-term goals of this research are to better understand the processes at the ocean surface that directly influence active and passive remote sensing.

SCIENTIFIC OBJECTIVES

The immediate objectives of this research are:

1. To better understand the interaction between short surface waves and turbulence, especially those interactions that influence surface processes that are of importance for passive and active remote sensing; and
2. To better understand microwave scattering by combined fields of waves and turbulence.

APPROACH

We have taken a three-pronged approach to this research with a combination of laboratory measurements of surface hydrodynamics and microwave scattering; field measurements from SIO pier, and theoretical modeling and comparisons with measurements. In collaboration with the PI, much of the day-to-day experimental and field work on this grant has been undertaken by Dr. Anatol Rozenberg, with detailed theoretical and numerical work by Dr. Alexey Fedorov who graduated during the course of this grant. All em scattering measurements have been made with a dual-polarized Ku-band (14GHz) Doppler scatterometer. Surface hydrodynamics have been measured with a combination of electromechanical wave gauges, a scanning laser slope gauge, and a Digital particle Imaging Velocimetry system. With assistance from Dr. Jaehne's group at SIO, during the course of this year construction was begun on an imaging slope gauge.

Much of the effort in the last year has focused on the role of parasitic capillaries and surface turbulence in microwave scattering. Laboratory experiments have been undertaken on microwave scattering by mechanically-generated and wind-generated decimetric waves generating parasitic capillary waves. Laboratory measurements have also been undertaken on the influence of mechanically-generated turbulence on surface waves and microwave scattering. A theory of nonlinear parasitic capillary waves with wind forcing and viscous dissipation has also been developed. Quantitative results require final numerical computation.

WORK COMPLETED

Work by a number of groups (including the SIO group) over the last five years or so has identified the presence of "fast scatterers" giving Doppler shifts greater than those that can be attributed to free Bragg scatterers, with evidence of varying degrees of certainty that the fast

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scatterers may be due to either parasitic capillary waves generated near the crests of longer decimetric waves, or breaking waves. In either case the scatters travel at or near the phase speed of the longer waves. In 1997, we published a paper demonstrating the effects of still longer waves or “swell” on this phenomenon and the complications that the fast scatterers lead to in using the scattering data to infer the properties of the longer waves (Rozenberg, Quigley & Melville, 1996). This work was extended during this year to show that scattering by mechanically-generated parasitic-capillary waves could be unambiguously associated with scattering by harmonics of the surface waves (Rozenberg, Quigley, Ritter & Melville, 1997). Bispectral techniques have been used to clearly show that under a range of conditions the fast scattering phenomenon is associated with nonlinear surface processes (Rozenberg, Melville, Ritter, Gottschall & Smirnov, 1997).

Given the evidence above, considerable effort has been devoted in the last year to the prediction of the properties of nonlinear waves generating parasitic-capillaries. A theory that takes into account nonlinearity, viscous boundary layers and wind-forcing has been developed. The theory ultimately requires numerical computation to obtain solutions for steady gravity-capillary waves (Fedorov, 1997; Fedorov & Melville, 1997). The predictions have been tested against laboratory measurements of mechanically-generated gravity-capillary waves with very good results. The theory and measurements show that surface tension leads to local maxima in the higher harmonics, consistent with resonant generation of parasitic capillary waves (Fedorov, Melville & Rozenberg, 1997).

Laboratory measurements on the scattering by breaking waves at grazing incidence (Rozenberg, Melville & Ritter, 1996) have shown that, as well as the large backscatter from the wave during breaking, the scattering persists for times comparable to the decay scale of the turbulence generated by the breaking wave (Rapp & Melville, 1990). This suggested that rather than just being an additional dissipation mechanism surface turbulence may play a more active role. To more closely examine these phenomena, surface slope and microwave scattering measurements by surface waves propagating through mechanically-generated turbulence have been undertaken. The rather striking result is that one effect of turbulence may be to enhance the generation of parasitic-capillary waves, thereby increasing the microwave backscatter (see Figure 1). The mechanism by which the parasitic capillary waves are generated is under active investigation.

RESULTS

During this year we:

1. Provided clear experimental confirmation that parasitic capillary waves may act as fast scatterers in a variety of conditions;
2. Developed a theory of nonlinear gravity-capillary waves including predictions of the parasitic-capillary waves;
3. Confirmed the theory by comparison with laboratory measurements of parasitic-capillary waves; and
4. Demonstrated that one consequence of wave-turbulence interaction is enhancement of the parasitic-capillary waves and consequent enhancement of the microwave scattering.

IMPACT/APPLICATION

These results should lead to broader application of microwave remote sensing techniques for the remote measurement of surface wave and mixing phenomena.

TRANSITIONS

Measurements of the surface geometry and microwave scattering by nonlinear gravity-capillary waves have been made available to Dr. Jim West of Oklahoma Sate University for comparison with his numerical models of microwave scattering.

RELATED PROJECTS

The PI is currently funded by ONR(Physical Oceanography, N00014-97-1-0277) with an AASERT enhancement (N00014-97-1-0644) under the Shoaling Waves DRI to study wave breaking and dissipation on the continental shelf using remote and in situ techniques. The PI is also funded by NSF (PO) to undertake laboratory measurements of Langmuir circulations (LC's) which are a form of coherent surface turbulence. There are issues of wave-turbulence interaction that are shared between the NSF/LC project and this project.

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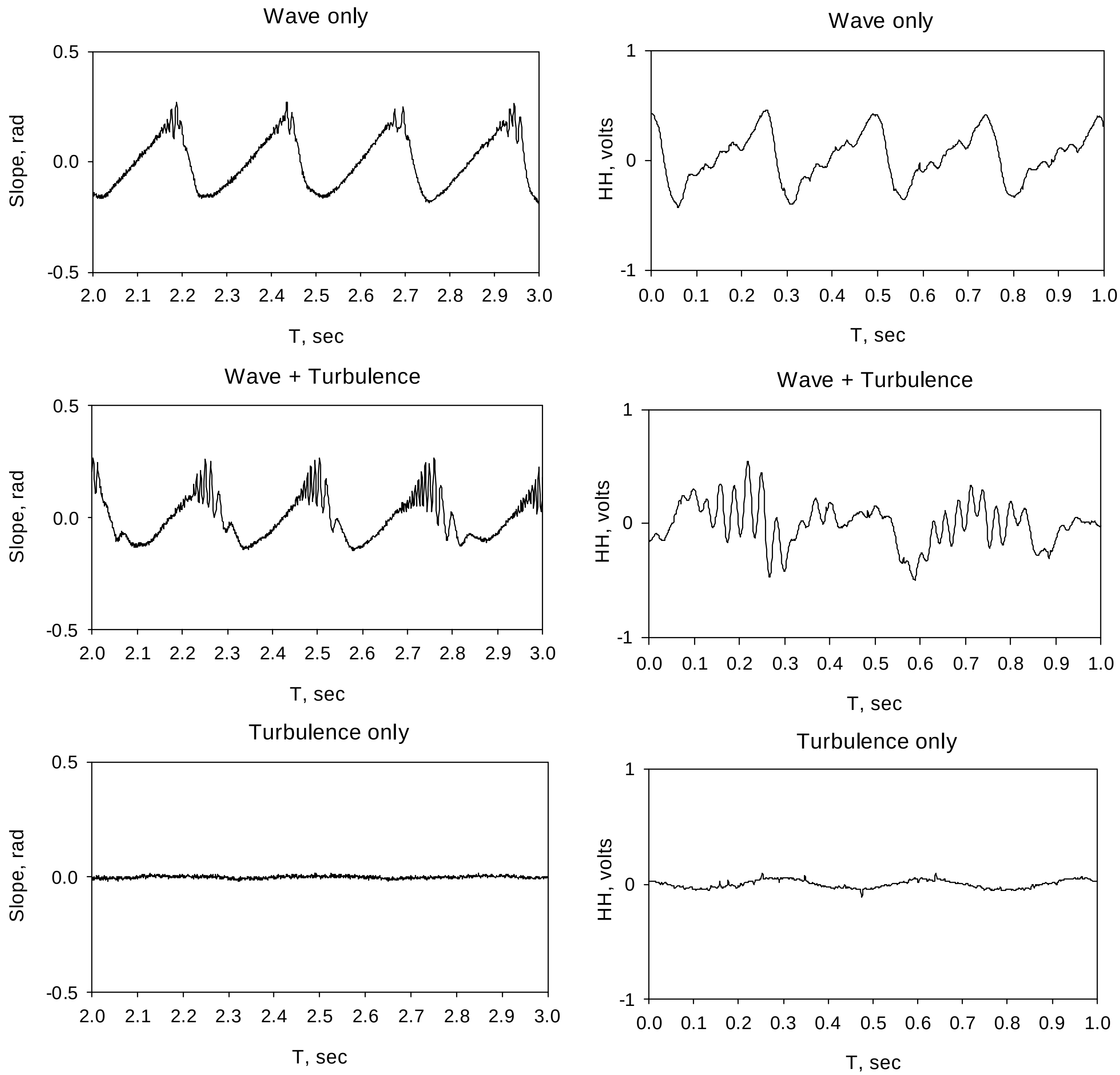

Figure 1. Slope time series of steep regular 4 Hz waves (left) and HH scattered signals (right) in a glass channel, waves only (top), waves + turbulence (middle), turbulence only (bottom). Ku-band scatterometer at 12° grazing angle.